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Multiband Fractal Antenna Deploying DGS Structure Simulation using HFSS for Wireless Applications

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***Abstract*: In this paper, rectangle and square shape slots are formed on rectangular micro-strip patch antenna which is different from conventional rectangular micro-strip patch antenna. It consists of four horizontal and four vertical square slots of fractal geometry with partial ground.**

Fractal geometry is designed to acquire the resonance at different frequency applications and to accomplish compact and miniature low profile antenna. The fundamental rectangular antenna structure is chosen and four iterations with partial ground plane are designed and simulated on HFSS. The increment of the iterations of fractal antenna increases no of resonances.

The proposed fractal antenna incorporates defected ground structure (DGS) of "U" shape on partial ground have multiband responses from frequency range of 1 to 20 GHz. The simulation results obtained for this antenna resonates at various frequencies at 3.54 GHz, 4.7 GHz, 5.8GHz, 7.6 GHz, 8.6GHz, 8.62GHz, 10.59GHz, 13.6GHz, 14.3GHz, 17.2GHz and 19.39 GHz. The simulated results demonstrate that the antenna can discover its utilization in various bands such as C band, K band and Ku band. The designed antenna is analyzed depending upon various parameters like return Loss, Gain, VSWR, directivity and data transmission.

***Keywords*: Fractal Antenna, Patch, Defective-Ground, DGS, Multiband, Multi-resonance, HFSS**

1. Introduction

Wireless communication technology makes our lives easy from last three decades. By using wireless appliances, we can communicate to each other without the boundaries of time and places. WLAN (wireless local area network) provide the facility to access to the internet without suffering from expensive cable and managing yards of unsightly.

In the cutting edge remote correspondence frameworks and scaling down the size of reception antenna, there is an extraordinary need of reception antenna having smaller size and multi-reverberation attributes. In the period of remote correspondence framework there is an incredible need of little size reception antenna for business applications. These radio wires likewise discover their utilization in military and RADAR applications. Multiband qualities of fractal receiving wire enables client to utilize single reception apparatus gadget to work more than a few number of recurrence groups.

Fractal radio wires are acquainted with have a solitary receiving wire which gives multi-resonance reaction over numerous groups of frequencies. The business administrators are going for a receiving wire framework which has great execution trademark like low profile design, multi-resonance reaction and minimal effort. Every one of these necessities of the administrators are satisfied by Microstrip fractal reception antenna. Microstrip radio wires have numerous favorable circumstances over straightforward microwave reception apparatus plan. They have properties like low profile, compact size, Multi-reverberation and minimal effort. The size of the regular Microstrip radio wire isn't reasonable for current remote correspondence supplies.

The decrease in the size of micro-strip reception apparatus without influencing the presentation parameters of regular micro-strip radio wire is critical in remote correspondence. This paper shows a structure of multiband fractal receiving wire with imperfect ground plane.

2. Fractal antennas and DGS

Fractal receiving wire applies a fractal geometry procedure developed by Benoit Mandelbrot in 1975.Fractal receiving wire is a reception apparatus with sporadic shape and self-comparative example structure. It is structured to build the border of fix material which can transmit inside an all-out surface zone of the fix fractal geometry configuration bears for the improvement of the receiving wire cluster and increment in the number of reverberation frequencies without influencing key parameters of radio wire. Fractals have parameter which rehashes them as indicated by their cycle factor. Cycle factor relies upon the fractal geometry plan contemplations. Fractal structures are acquainted with acquire higher request structure to cover progressively number of recurrence groups. Fractal radio wire configuration structure is a answer for lessen the physical molded and size of radio wire. Fractals have some remarkable properties and highlights:

- Fractal set has low profile structure.
- Fractals have self-comparative property.
- They have multiband and multi-administration include.
- They offer improved addition and data transmission inside the less physical shape.
- They are more dependable and have ease than other ordinary receiving wires.

The Defective-Ground is utilized to adjust plan for decrease in physical zone of the receiving wire. Defected ground structure (DGS), commonly used for enhancing the performance of printed circuits and antennas, has been relatively a new area of research. Single or multiple defects are usually created on the ground plane (GP) to perturb the current distribution and to introduce resonant properties which are modelled using an equivalent L-C combination.

In this technique, a defect or cut is used in the ground plane to modify the radiation characteristic of the whole antenna; this defect made in the ground will further change the behaviour of the radiation of the patch antenna.

3. Proposed antenna structure

The rectangle formed Micro-strip fix fractal reception apparatus is proposed in this work to get the multi administration also, multiband tasks. The essential structure for radio wire is chosen on the sorts of normal plan shapes accessible for fractal fix receiving wire. The higher request configuration structure is acquired through the fractal age system.

A. Fractal generation technique

The fractal shaped can be designed through repeating the iteration of the basic design structure. In this simulation work the "square" shape slot is selected as a basic block for antenna design. The Iterations applied in this design are followed by these steps:

Step 1: Four rectangular slots are inserted on rectangular micro-strip patch horizontally.

Step 2: Four more rectangular slots are designed above rectangular micro-strip patch antenna.

Step 3: Four more rectangular slots are designed on patch vertically.

Step 4: Apply DGS structure and addition of three rectangular slits on patch to improve gain and bandwidth.

B. Iterations of Fractal structure

Iterations are the redundant undertakings done on the fundamental structure to get the fractal shape plan. The high request reception apparatus structure is acquired by applying the iteration methodology procedure on the essential square fix structure. The fundamental cycle is at first applies inside a unique square. It results in producing number of squares with the cycle request equivalent to one. A similar methodology is pertinent on every single residual cycle The Fig 1. shows the steps ventures for the age of higher-orders fractal shape radio wire.

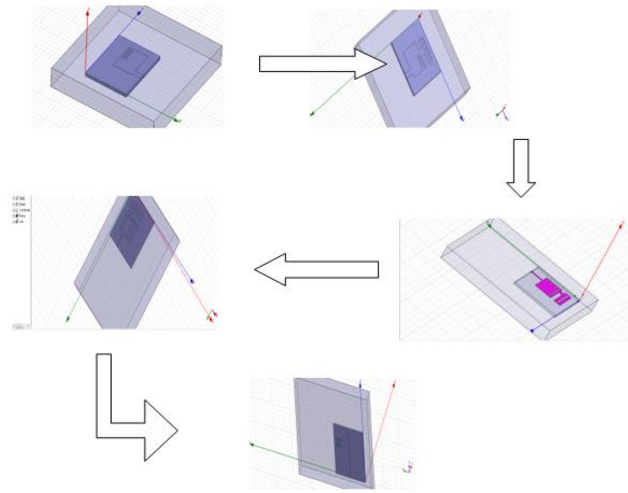


Fig. 1. Ventures for the age of higher-orders fractal shape radio wire

This design is a miniaturized compact antenna design to obtain multiband characteristics with reduced physical shape.

4. Antenna design considerations

For this design, the basic resonance frequency is 3.75 GHz. The analysis of rectangular micro-strip patch is based upon the basic equations for calculating the dimensions of patch.

In a dielectric substrate, the effective dielectric constant is calculated using following equation:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\,\frac{h}{w}\right]^{\frac{1}{2}}$$

Where,
ε_r is the dielectric constant of the substrate
h is the thickness of the substrate
W is the width of the patch

$$L_{eff} = \frac{C}{2f_0\sqrt{\varepsilon_{reff}}}$$

Where, f_0 is the center frequency of the antenna.

The width for the patch can be calculated by using the following equation

$$W = \frac{C}{2f_0\sqrt{\frac{\varepsilon_r + 1}{2}}}$$

$$\lambda = \frac{C}{f_0\sqrt{\varepsilon_{reff}}}$$

For the transmission line, the length is approximately

0.75.Where λ is the wavelength of the antenna.

The real length for the patch can be calculated by L=Leff-2ΔL, where

$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

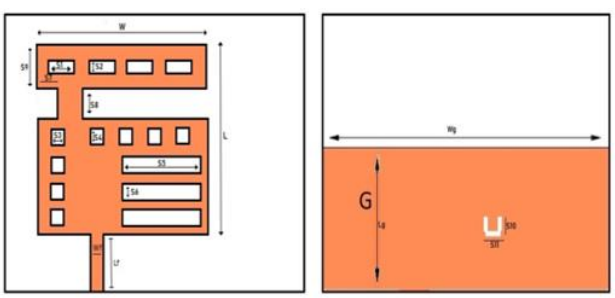
The patch dimensions for proposed antenna are 15* 24 mm^2 which is very compact and miniature low profile antenna. This antenna has resonating frequency of 3.75 GHz. The iteration factor chosen for this design is rectangular slots which is inserted horizontally and vertically.

The design considerations of the design are shown with the values in Table 1.

Table 1
Optimised dimensions of proposed antenna

Parameter	Unit (mm)
L	15
W	24
S1	3
S2	2
S3	2
S4	2
S5	10
S6	1.5
G	20
S7	4
S8	3
S9	6
S10	6
S11	2
Lf	11
Wf	2

The dimensions of the designed structure are shown in Fig. 2.



(a) front view (b) Back view

Fig. 2. Proposed antenna design

5. Simulation result and analysis

All the antenna structures are simulated using Ansoft HFSS Version 13.0 software. For 1st step resonance frequency obtained after all the simulations is at 5.625 GHz with gain of -22.32 dB and at 7.22 GHz with return loss of -15.1 dB.

For 2ndorder of iteration, the resonance is obtained at different frequencies such as 9.6, 14.4, 16.9, 19.2, 22.6 and 28.796 GHz.

The 3rd order iteration provides multi band antenna resonating at various frequencies and return loss obtained is -30.66dB at 3.54 GHz, -15.7dB at 4.7 GHz, -20.3dB at 5.8GHz, -15.4dB at 7.6 GHz, -17.8dB at 8.6GHz, -17.4dB at 8.62GHz, -13.5dB at 10.59GHz, -35.99dB at 13.6GHz, -20.7dB at 14.3GHz, -24.3dB at 17.2GHz and -24.4dB at 19.39GHz.

The 4th order iteration also gives multi resonance at 5 different frequencies which are as follows and return loss is also less than -10 dB. Various bands include return loss of -12.05 dB at 5.72 GHz, -40 dB at 7.3 GHz, -10.86 dB at 9 GHz, -10.27 dB at 10.96 GHz, -14.38 dB at 13.51 GHz, -19.81 dB at 16.07 GHz and -20.85 dB at 19.16 GHz.

The modified 3rd order of iteration gives the maximum eleven resonant frequencies. The simulated S-parameters results for different iterations are described in the figures below.

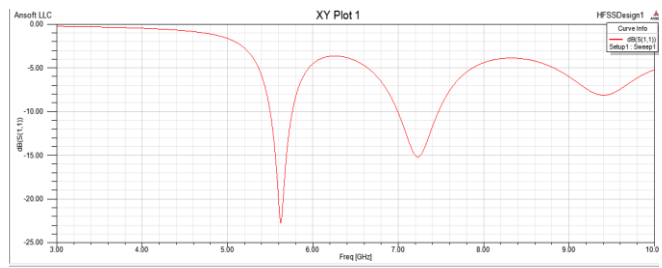


Fig. 3. 1st order S-parameter (Return loss)

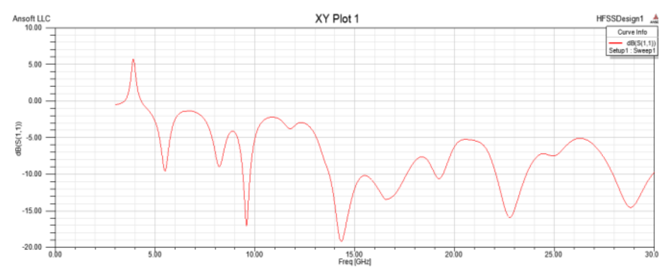


Fig. 4. 2nd order S-parameter (Return loss)

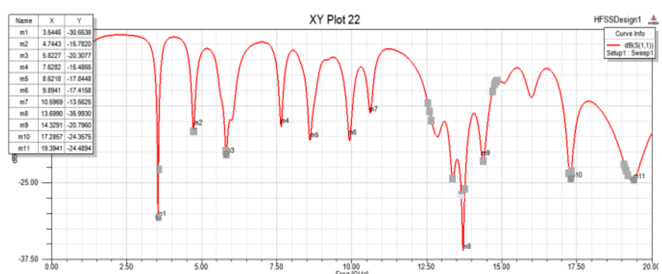


Fig. 5. 3rd order S-parameter (Return loss)

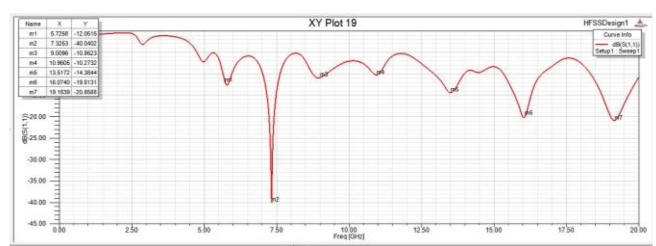


Fig. 6. 4th order S-parameter (Return loss)

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Table 2
Number of resonance frequencies with iteration order

Iterations Numbers	Resonance Frequencies for iterations in Giga Hertz
1st	5.625 GHz, 7.22 GHz
2nd	9.6, 14.4, 16.9, 19.2, 22.6 and 28.796 GHz
3rd	3.54 GHz, 4.7 GHz, 5.8GHz, 7.6 GHz, 8.6GHz, 8.62GHz, 10.59GHz, 13.6GHz, 14.3GHz, 17.2GHz and 19.39GHz
4th	5.72 GHz, 7.3 GHz, 9 GHz, 10.96 GHz, 13.51 GHz, 16.07 GHz and 19.16 GHz.

The VSWR plot of antenna is analyzed to get the impedance matching compatibility of antenna. It is necessary that the value of VSWR should be below unit value 2.

The simulation results of the VSWR for different iterations are described in following figures.

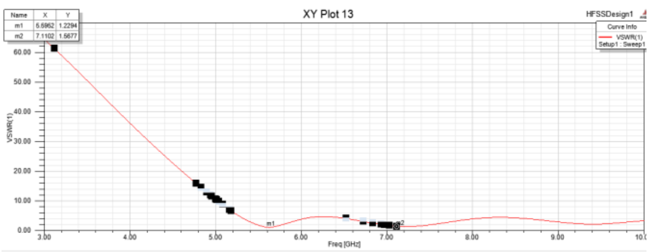

Fig. 7. 1st orders VSWR

Above figure shows that the value of VSWR for rectangular patch loaded with four square slot is lower than 2 i.e. 1.22 at 5.592 GHz and 1.56 at 7.11 GHz.

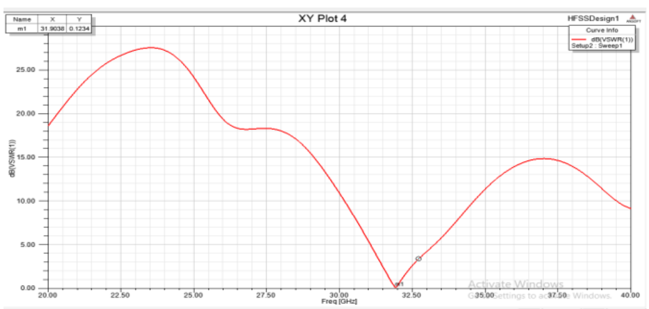

Fig. 8. 2nd orders VSWR

Above figure shows that the value of VSWR for antenna is lower than 1 i.e. 0.12 at resonating frequency.

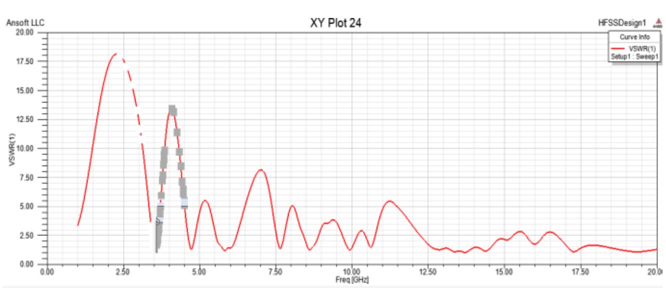

Fig. 9. 3rd orders VSWR

The different values of multiband antenna having VSWR of 1.3 at 3.5GHz, 1.4 at 4.7GHz, 1.26 at 5.7 GHz, 1.59 at 7.688 GHz, 1.28 at 8.5GHz, 1.28 at 9.9 GHz, 1.6 at 10.64 GHz, 1.3 at 12.82 GHz,1.04 at 13.67 GHz,1.22 at 14.30 GHz,1.80 at 15.9 GHz and 1.16 at 17.2 GHz.

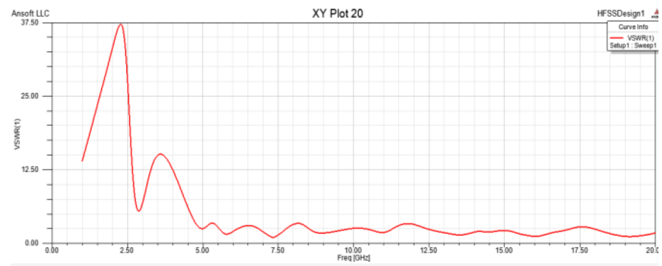

Fig. 10. 4th orders VSWR

Different values of VSWR as follows at different frequency as follows 1.6 at 5.79 GHz, 1.09 at 7.36 GHz, 1.97 at 8.70 GHz, 1.88 at 10.96 GHz, 1.47 at 13.50 GHz, 1.21 at 16.04 GHz and 1.21 at 19.04 GHz.

The radiation pattern of antenna depends on the directivity and gain plot. The directivity of antenna determines the direction of the radiations of the antenna. The gain plot for the proposed antenna is shown in figure.

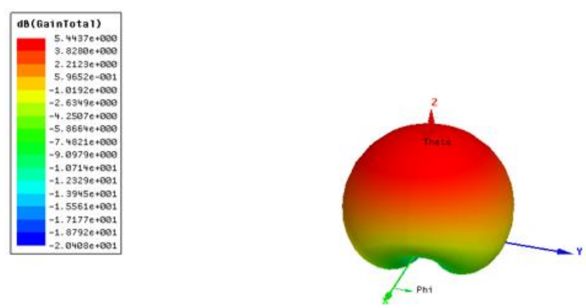

Fig. 11. Gain plot for the proposed antenna

6. Conclusion

The fractal antenna simulation is completed on HFSS programming variant 13.0. The outcomes are examined for various working frequencies in the scope of 1GHz to 20GHz. With increment in requests of emphases, the quantity of resonance frequencies is expanded by one. The radio wire discovers its utilization in multi-administration applications. Finally, quantities of resounding frequencies are eleven in adjusted third emphasis. Highlight of improved addition is accomplished by decreasing the size of ground plane. The reception apparatus gives the best outcome at resonating frequency of 7.3 GHz.

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